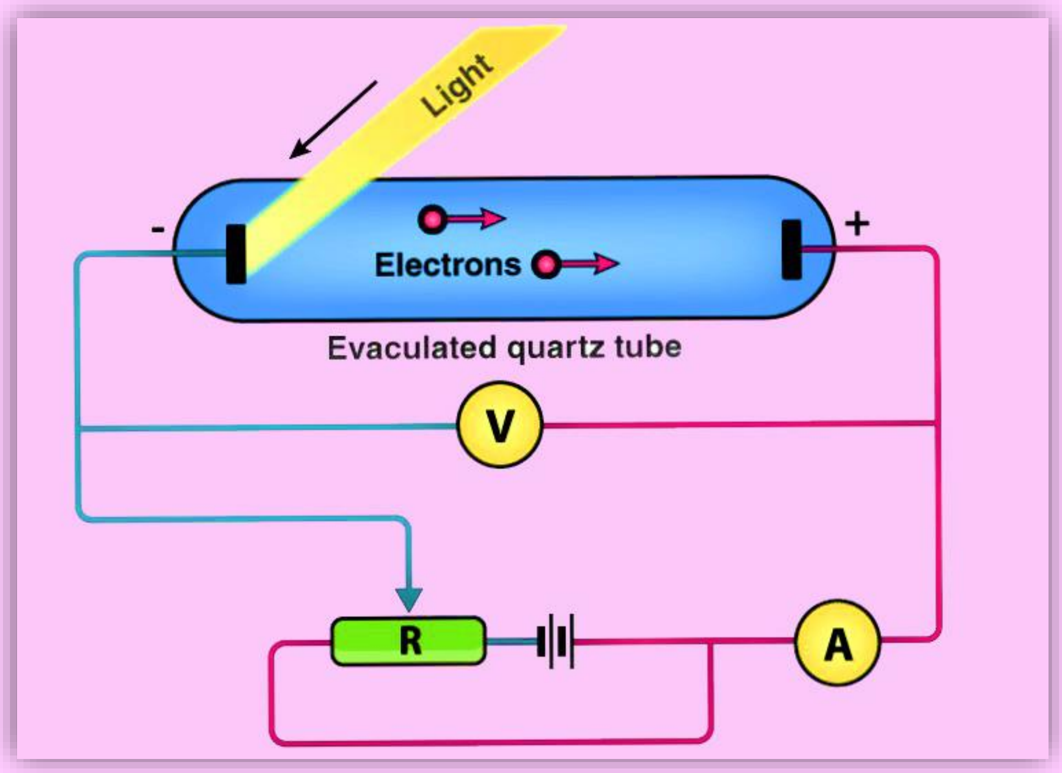
11.Dual Nature of Radiation and Matter



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DUAL NATURE OF RADIATION AND MATTER

PLANCK'S QUANTUM THEORY OF LIGHT

(1) The energy of one photon is proportional to its frequency
(2) $E \propto \nu$, $E = h\nu$
h = Plank's constant
$= 6.62 \times 10^{-34}$ Js
(3) Energy of any light or radiation is one integral multiple of $h\nu$.
$E = Nh\nu$
(4) Energy of one photon.
$E = h\nu = \frac{1240}{\pi(nm)} eV$

DUAL NATURE OF LIGHT

de – Broglie wavelength, $\lambda = \frac{h}{m\nu}$ & $2\pi r = n\lambda$

• $m\nu r = \frac{nh}{2\pi}$

This is Bohr quantisation Condition

PROPERTIES OF PHOTONS

(1) Photon is just a packet of energy.
(2) Energy of photon does not change with medium.
(3) Photon can not be deflected by electric field and magnetic field.
(4) Momentum of photon $|\vec{P}| = m \times c = \frac{h}{\lambda} = \frac{E}{C}$
(5) Intensity of light beam = $\frac{\text{Energy}}{\text{area} \times \text{time}}$

PHOTON EMITTED PER SECOND

(1) $E = Nh\nu$
(2) Power, $P = Nh\nu$
$\Rightarrow = \frac{p}{h\nu} = \frac{p\lambda}{hc}$
Number of photon per second = $\frac{\text{Power}}{\text{energy of one Photon}}$

PHOTON FLUX

• Photon flux is no. of photon incident normally to a surface per seconds
• $\phi = \frac{n}{A} = \frac{P}{h\nu}$

FORCE AND RADIATION PRESSURE EXERTAD BY A LIGHT BEAM

(1) $n = \frac{p\lambda}{hc}$
(2) momentum of one photon = $\frac{h}{\lambda}$ momentum imparted per second = $n \times \frac{h}{\lambda} = \frac{P}{C}$
$\Rightarrow$ Force exerted = $\frac{P}{C}$
(3) Radiation Pressure = $\frac{F}{A} = \frac{P}{CA} = \frac{I}{C}$

PHOTOELECTRIC EFFECT

(1) It is a phenomenon of ejecting electrons by falling light of suitable frequency on a metal
(2) Ejected electrons are called photoelectrons.
(3) Current flowing due to the photoelectrons is called photocentric current

LAWS

(1) No emission takes place below the threshold frequency.
(2) Above threshold frequency, no. of photoelectrons emitted per seconds is directly proportional to intensity of radiation
(3) The emission of photoelectrons is an instantaneous process.
(4) Above threshold frequency, K.E (max) depends on frequency

WORK FUNCTION

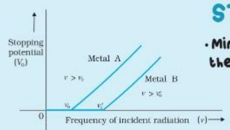
• Minimum energy required for getting a free electron away from the metal surface.
• work function $(\phi_o) = h\nu_o$

$\nu_o = \frac{\phi}{h}$ = threshold frequency

EINSTEIN'S PHOTOELECTRIC EQUATION

• The electron is emitted with maximum K.E
$K.Emax = h\nu - \phi_o$
$h\nu = K.Emax + \phi_o$
• Range of K.E.
$0 \le K.E._{photoelectrons} \le h\nu - \phi_o$

STOPPING POTENTIAL

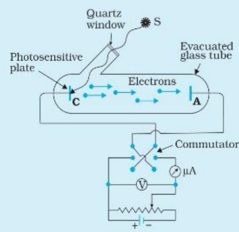


• Minimum negative potential required to stop the electron of maximum K.E.

$V_o = \frac{K.E_{max}}{e} = \frac{h}{e}(\nu - \nu_o)$ Volts

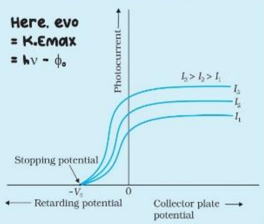
EXPERIMENTAL STUDY

• The emission of electrons causes flow of electric current in the circuit.

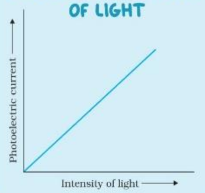


EFFECT OF POTENTIAL

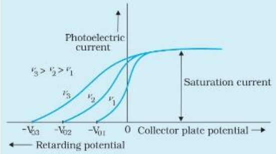
Here, eV_o
$= K.Emax$
$= h\nu - \phi_o$



EFFECT OF INTENSITY OF LIGHT



EFFECT OF FREQUENCY OF INCIDENT



PARTICLE NATURE OF LIGHT

(1) In interaction of radiation with matter, radiation behaves as if is mode of particles called photons
(2) $E = h\nu$ and $p = \frac{h\nu}{c}$
(3) In a photon – particle collision, total energy and total momentum are conserved.

MATTER WAVE THEORY

• de – Broglie wavelength associated with moving particles, $\lambda = \frac{h}{p}$
• K.E of particle = $\frac{1}{2}mv^2 = \frac{p^2}{2m}$
• momentum, $P = mv$
$\sqrt{2m \times K.E}$

FOR UNCHARGED PARTICLES

$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m \times K.E}}$

FOR ACCELERATED CHARGED PARTICLES

$\lambda = \frac{h}{\sqrt{2m \times K.E}}$

V = potential difference

SPECIAL CASE FOR ELECTRON

$\lambda = \frac{1.227}{\sqrt{V}}$ nm

And

$V = \frac{150.1}{[\lambda(\mathring{A})]^2}$ Volt

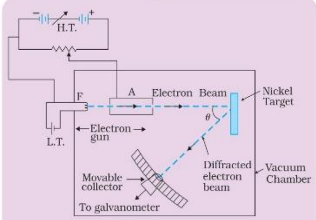
FOR GASEOUS MOLECULES

$K.E = \frac{3}{2}KT$

$\Rightarrow \lambda = \frac{h}{\sqrt{2m \times \frac{3}{2}KT}}$

$\Rightarrow \lambda = \frac{h}{\sqrt{3mKT}}$

DAVISSON-GERMER EXPERIMENT



• at ϕ = 50o and accelerating potential = 54 V, maxima is obtained
• This experiment confirmed the wave nature of electron.

Dual Nature of Radiation and Matter

Photoelectric effect

Electrons are the common constituents of all atoms and hence of all materials. The electrons inside a material are held by electrostatic forces, so that they cannot by themselves come out of the material. By supplying proper energy from outside, some of the electrons in a material can be made to come out, and this phenomenon is known as *electron emission.* The minimum energy required to remove an electron from a material is called the *work function,* of that material.

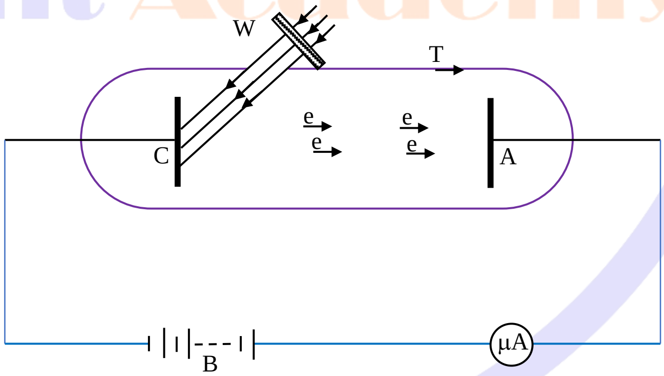
Types of Electron Emission

According to the free electron theory of metals, a large number of loosely bound electrons exist in a metal. Thus, electrons can be liberated from a metal surface by any one of the following methods.

1. The process of emission of electrons from the surface of a metal by heating it is called **thermionic emission.**
2. The process of emission of electrons from the surface of a metal by using radiation of suitable frequency (UV, Visible, IR etc.,) of suitable frequency is called **photoelectric emission.**
3. The process of emission of electrons from the surface of a metal, using an electric field is called **field emission** or **cold emission.**
4. The process of emission of electrons from the surface of a metal, using a beam of accelerated charged particles is called **secondary emission.**

Photoelectric effect is the phenomenon of emission of electrons from a surface when radiation of suitable frequency falls on it.

T = Evacuated tube
C = Photo cathode
A = Collector plate
W = quartz window
B = Voltage source
μA = microammeter



Experimental results

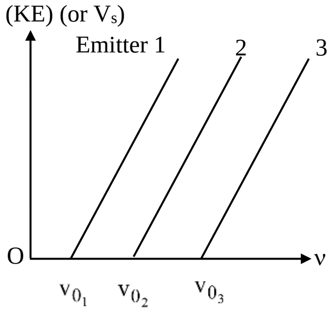
1. **For a given material (photosensitive cathode), there is a frequency of radiation, below which photoelectric emission does not take place, whatever may be the intensity. This minimum frequency is called threshold frequency (ν_0), with respect to that material.**

   The wavelength corresponding to the threshold frequency is called the limiting wavelength (λ_0).
   For photoelectric effect to take place, $\nu_{incident} > \nu_0$ and hence $\lambda_{incident} < \lambda_0$.
2. **Photoelectric effect is almost instantaneous.**

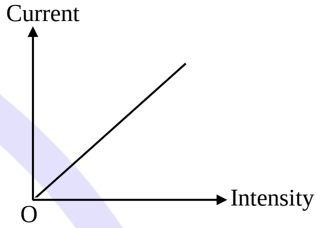
3. **When the frequency of radiation incident on a photoemission surface is increased above the threshold frequency, the kinetic energy of the photoelectrons increases linearly.**

A graph of maximum kinetic energy of the emitted photoelectrons versus the frequency of radiation is a straight line.

The slope is same for all emitters and thus, a set of parallel straight lines is obtained.



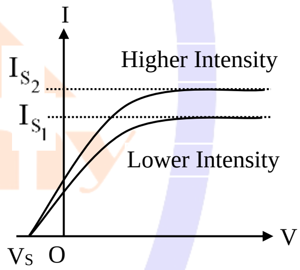
4. **When $\nu > \nu_0$, if the intensity of the incident radiation is increased, the number of photoelectrons liberated and hence the photoelectric current increases.**



5. **If the collector potential with respect to the emitter is reduced to zero, current does not reduce to zero. If the collector potential is made negative with respect to the emitter and then increased, the current decreases. At a particular negative potential (V_s), the photoelectric current becomes zero. This potential is called stopping potential.**

Kinetic energy is eV is numerically equal to stropping potential in volt.

6. **As the collector potential (+V w.r.t. emitter) is increased, the photoelectric current (I) increases gradually to a certain constant value called the saturation current (I_s).**



Einstein's explanation of photoelectric effect

Assumed that a beam of light is composed of discrete packets of energy called **photons**, which travel with the velocity of light. The energy of a photon is given by

$$\boxed{E = h\nu = \frac{hc}{\lambda}}$$

where $h \rightarrow$ Planck's constant = 6.625×10^{-34} J s

$\nu \rightarrow$ frequency of incident light (in hertz)

$c \rightarrow$ speed of light in free space = $3 \times 10^{8}\,\text{m s}^{-1}$

$\lambda \rightarrow$ wavelength of light incident on the photosensitive surface (in metre).

A metal has a large number of free electrons. Though these electrons are free to move within the metal, they cannot come out of the metal surface. A certain minimum energy is required to pull them out. This is called the **work function.**

Hence, the energy equation can be written as,

$$\begin{bmatrix}\text{Energy of the}\\ \text{incident photon}\end{bmatrix} = \begin{bmatrix}\text{photoelectric}\\ \text{workfunction}\end{bmatrix} + \begin{bmatrix}\text{maximum kinetic energy of}\\ \text{the photoelectron}\end{bmatrix}$$

$$h\nu = W + \frac{1}{2}mv^2_{max} \quad \Rightarrow \frac{1}{2}mv^2_{max} = h\nu - W \quad \Rightarrow (KE)_{max} = E - W$$

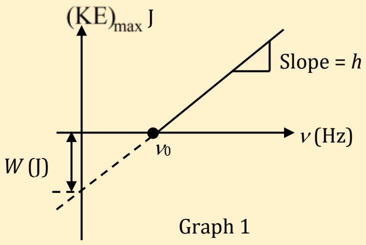
where m = mass of an electron, v_{max} = maximum velocity of the photo electron and W is the work function, of the material.

This equation is called **Einstein's photoelectric equation**.

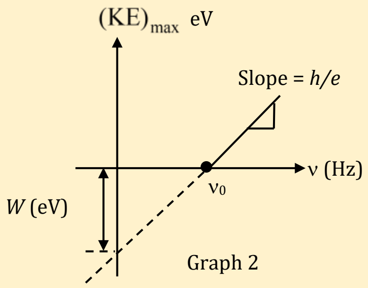
Einstein's photo electric equation can be also written as

$$\frac{1}{2}mv_{max}^2 = h(\nu - \nu_0)$$

- **For quick calculation**, $E = \frac{hc}{e\lambda} = \frac{6.625\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times\lambda\times10^{-10}} \cong \frac{12400}{\lambda(\overset{0}{A})}eV = \frac{1240}{\lambda\ (nm)}eV$
- Similarly, work function = $W \cong \frac{12400}{\lambda_0(\overset{0}{A})}eV = \frac{1240}{\lambda_0\ (nm)}eV$
- $v_{max} = \sqrt{\frac{2eV_s}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times V_S}{9.1\times10^{-31}}} \cong 6\times10^5\sqrt{V_S}\ m\,s^{-1}$
- Physical significance of various geometrical terms used in the following graphs.



Graph 1



Graph 2

Geometrical terms	Graph 1	Graph 2
Abscissa	Frequency in Hz	Frequency in Hz
Ordinate	$(KE)_{max}$ in J	$(KE)_{max}$ in eV
Slope	h	h/e
x-intercept	Threshold frequency ν_0	Threshold frequency ν_0
y- intercept (negative)	W in J	W in eV $\equiv V_s$ in volt

Photocells

A photocell device which converts light energy into electrical energy. Three major types are:

(i) Photoemissive cell

(ii) Photovoltaic cell (used as a source of emf)

(iii) Photoconductive cell

Applications of photocells

Photocells have several applications. For example,

1. In cinematography for reproduction of sound.
2. In television cameras for converting optical images into electrical signals.
3. In exposure meters fitted to cameras (combination of a photocell and galvanometer).
4. For automatic switching, depending on the presence or absence of light.
5. In burglar alarm, fire alarm etc.
6. In photometry to compare illumination due to two sources of light.
7. In identification of colour.

8. For measurement of opacity or turbidity.
9. In smoke detection.
10. In the construction of solar panels.

Illustrations

1. Out of the following, the incorrect statement is

(A) wave theory can explain satisfactorily interference, diffraction and polarization

(B) wave theory can explain photoelectric effect

(C) Max Planck's hypothesis of quantization was used by Einstein to explain photo electric effect.

(D) Wave theory could not explain the energy distribution in the Black body spectrum.

Ans (B)

Explanation of photoelectric threshold requires the absorption of energy by the emitted electron in one shot. In other words, the electron to be released should get the complete energy requirement at one go which is possible only when the incident energy is treated as a photon. Further on increasing the frequency of the incident radiation above the threshold the kinetic energy of the photoelectrons increases. These concepts are clear from Einstein's photoelectric equation.

If a wave could supply energy continuously after sufficient time photoelectrons should have been liberated for incident light of any wavelength. This is not seen experimentally.

2. Of the following, the graph which represents the variation of energy (E) of a photon with wavelength (λ) of the radiation is

(A) (B) (C) (D)

Ans (B)

The energy of a photon is given by $E = \frac{hc}{\lambda} \Rightarrow E \propto \frac{1}{\lambda}$.

Therefore the graph of E v/s λ is rectangular hyperbola.

3. The threshold wavelength for sodium is 680 nm. The photoelectric workfunction in eV is

$(h = 6.62 \times 10^{-34}\ Js,)$

$1\ eV = 1.6 \times 10^{-19}\ J,\ c = 3 \times 10^{8}\ m\ s^{-1}$

(A) 0.1825 (B) 1.825 (C) 18.25 (D) 18.25×10^{-19}

Ans (B)

We know that, the work function of a metal is given by

$$W = h\nu_0 = \frac{hc}{\lambda_0} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{9}}{680 \times 10^{-9}} = 1.825\ eV$$

or $W \cong \frac{1242}{680(nm)} \cong 1.8\ eV$ or $\frac{12420}{6800(\overset{0}{A})} \cong 1.8\ eV$

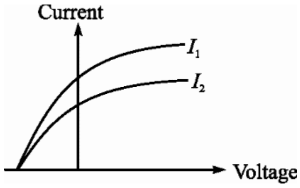
4. Figure shows the plot of photoelectric current with the applied potential difference for two different intensities I_1 and I_2 for light of frequencies ν_1 and ν_2 respectively such that $\nu_1 > \nu_2 > \nu_0$ where ν_0 = threshold frequency. From the graph, it can be concluded that

(A) $I_1 > I_2$ because $\nu_1 > \nu_2 > \nu_0$

(B) $I_1 < I_2$ because $\nu_1 < \nu_2$

(C) $I_1 = I_2$ because ν_1 and ν_2 are both greater than ν_0

(D) no comparison can be made from the graph since values of ν are not defined



Ans (A)

The saturation current depends on the intensity of the radiation and not on ν as long as $\nu > \nu_0$. Since the saturation current for the intensity I_2 is less than that for I_1, intensity I_2 is less than intensity I_1.

5. When a monochromatic point source of light is at a distance of 0.2 m from a photocell, the stopping potential (cut off voltage) and the saturation current are found to be respectively 1 volt and 27 mA. If the same source is placed at a distance 0.6 m from the cell then

(A) the stopping potential will be 0.25 V and current will be 27 mA

(B) the stopping potential will be 1 volt and the current will be 3 mA

(C) the stopping potential will be 1 volt and the current will be 9 mA

(D) the stopping potential and the current will be same as before.

Ans (B)

When the distance of the source is varied, only the intensity changes but the frequency remains constant. The stopping potential depends on the frequency of the radiation.

Therefore it remains constant. Intensity $\propto \frac{1}{d^2}$

but current I ∝ (Intensity) ⇒ $\therefore$ Current $\propto \frac{1}{d^2}$

$$\frac{I_2}{I_1} = \left(\frac{d_1}{d_2}\right)^2$$

$$I_2 = \left(\frac{0.2}{0.6}\right)^2 I_1 = \frac{1}{3^2} \times 27 \Rightarrow I_2 = 3 \text{ mA}$$

6. A photosensitive metal is first illuminated with the radiation of wavelength 400 nm and then with radiation of wavelength 800 nm. The change in the maximum kinetic energy of the photoelectron assuming that both wavelengths can cause photoelectric emission is

(A) 0.55 eV (B) 1.55 eV (C) 2.0 eV (D) 1.0 eV

Ans (B)

$$E_{k_1} - E_{k_2} = E_1 - E_2$$

Since $\lambda_2 = 2\lambda_1, E_2 = \frac{E_1}{2}\left(\because E_k \propto \frac{1}{\lambda}\right)$

$$\Rightarrow \quad \Delta E_k = E_1 - \frac{E_1}{2} = \frac{E_1}{2}$$

E_k (in eV) $\cong \frac{12420}{\lambda(\text{Å})}$

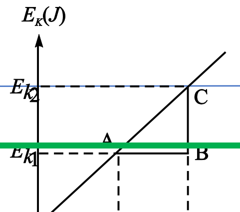
$$E_1 \cong \frac{12400}{4000\text{Å}} \cong 3.13\text{eV} \quad E_2 \cong \frac{12400}{8000\text{Å}} \cong 1.55\text{eV}$$

$\Rightarrow E_1 - E_2 = \Delta E_k \approx 1.55$ eV

7. The slope of the graph of the maximum kinetic energy in joule of the photoelectrons versus the frequency difference $(\nu - \nu_0)$ in Hz will be

(A) Planck's constant h (B) $\frac{h}{e}$ (C) $\frac{e}{h}$ (D) $\frac{1}{h}$

Ans (B)



$$\text{Slope} = \frac{BC}{AB} = \frac{E_{k_1} - E_{k_2}}{\nu_2 - \nu_1} \quad \text{or} \quad \text{slope} = \frac{\Delta E_k}{\Delta \nu}$$

$\therefore$ Slope = h (Planck's constant)

8. A and B are two metals with threshold frequencies 1.8×10^{14} Hz and 2.2×10^{14} Hz. Two identical photons of energy 0.825 eV each are incident on them. Then photoelectrons are emitted from

(A) A alone (B) B alone (C) from both A and B (D) from neither A nor B

Ans (A)

$$(\nu_0)_A = 1.8 \times 10^{14}\,\text{Hz}, \; (\nu_0)_B = 2.2 \times 10^{14}\ \text{Hz}$$

$$\text{Work function (in eV)} = \frac{h\nu_0}{e} \approx \frac{6.6 \times 10^{-34}}{1.6 \times 10^{-19}}\nu_0 \approx 4 \times 10^{-15}\nu_0$$

$$\therefore \quad W_A = 4 \times 10^{-15} \times 1.8 \times 10^{14} = 0.72\ \text{eV}$$

$$W_B = 4 \times 10^{-15} \times 2.2 \times 10^{14} = 0.88\ \text{eV}$$

E_k = Energy of photon = 0.825 eV.

Since $E_k > 0.72$ eV, photoelectric effect is possible in metal A only.

9. Light from a source is incident on two photocathodes of work function 3 eV and 1.5 eV respectively. The incident light has an energy of 4.5 eV. Then the ratio of maximum velocities of electrons in the two cases are

(A) $\left(\frac{v_1}{v_2}\right)_{max} = \frac{1}{2}$ (B) $\left(\frac{v_1}{v_2}\right)_{max} = \frac{1}{\sqrt{2}}$ (C) $\left(\frac{v_1}{v_2}\right)_{max} = \frac{1}{3}$ (D) $\left(\frac{v_1}{v_2}\right)_{max} = \frac{1}{\sqrt{3}}$

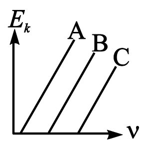
Ans (B)

$h\nu = h\nu_0 + E_k$; $\therefore$ $E_k = h\nu - h\nu_0$

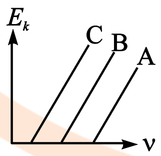
$$\frac{1}{2}mv_1^2 = 4.5 - 3 = 1.5\ \text{eV} \; ; \; \frac{1}{2}mv_2^2 = 4.5 - 3 = 1.5\ \text{eV} = 3\ \text{eV}$$

$$\therefore \frac{v_1^2}{v_2^2} = \frac{1}{2} \quad \therefore \frac{v_1}{v_2} = \frac{1}{\sqrt{2}}$$

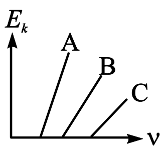
10. The work functions of three metals A, B and C are W_A, W_B and W_C respectively. They are in the decreasing order. The correct graph between kinetic energy and frequency ν of incident radiation is



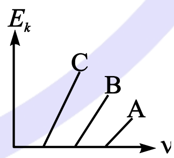
(A)



(B)



(C)



(D)

Ans (B)

Irrespective of the photo sensitive material used, the slope of each line should be same, since slope = $\frac{h}{e}$.

Since, $W_A > W_B > W_C$, ; $(\nu_0)_A > (\nu_0)_B > (\nu_0)_C$

Thus, the correct order is C, B, A.

(A) indicates $(\nu_0)_A < (\nu_0)_B < (\nu_0)_C$

$\therefore$ A is not possible. ; Options (C) and (D) are not possible since the graphs are not parallel.

Dual Nature of Matter

Matter Waves (de Broglie Waves)

In order to explain the phenomena of reflection, refraction, interference, diffraction, polarization, etc., light has to be regarded as *waves*. But to account for other phenomena such as photoelectric effect, Compton effect, Raman effect etc, light has to be regarded as particles called *photons*, which are discrete packets of energy. Thus, light can behave as a wave and also as a particle. This is called **dual nature of light.**

A material particle in motion exhibits wavelike characteristics and the associated wave is called a **matter wave** or a **de Broglie wave.**

If m is the mass of a particle travelling with a speed v, the de Broglie wavelength λ of the wave associated with the particle, is given by $\lambda = \frac{h}{mv}$. It is independent of charge (if any) on the particle.

Expression for λ

- $\lambda_{\text{de Broglie}} = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE_k}}$, E_k = kinetic energy of the particle
- $\lambda_{\text{de Broglie}} = \frac{h}{\sqrt{2meV}}$, V = accelerating potential applied to the charged particle
- $\lambda_{\text{electron}} = \sqrt{\frac{150}{V}}\ \text{Å} = \frac{12.27}{\sqrt{V}}\ \text{Å} \simeq \frac{1.23}{\sqrt{V}}\ \text{nm}$ (V = accelerating potential)

Uncertainty principle

It is not possible to measure both the position and momentum of an electron (or any other particle) at the same time exactly. There is always some uncertainty (Δx) in the specification of position and some uncertainty (Δ_p) in the specification of momentum, such that

$$\Delta x\ \Delta p \approx \hbar \text{ (where } \hbar = \frac{h}{2\pi},\ h = \text{Planck's constant)}$$

Davisson and Germer experiment

Davisson and Germer's experiment confirmed the existence of matter waves, by observing electron diffraction.

- Davisson and Germer observed diffraction effects with beams of electron scattered by crystals.
- The experiment was performed by varying the accelerating voltage from 44 V to 68 V. It was noticed that a strong peak appeared in the intensity of the scattered electrons for an accelerating voltage of 54 V at a scattering angle θ = 50°
- The appearance of the peak in a particular direction is due to the constructive interference of waves associated with electrons scattered from different layers of the regularly spaced atoms of the crystals.
- The de Broglie wavelength λ associated with an electron is $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

$$= \frac{1.23}{\sqrt{v}}\ \text{nm} = \frac{1.23}{\sqrt{54}}\ \text{nm} = 0.167\ \text{nm}$$

This is in good agreement with wavelength of electrons obtained by electron diffraction measurement.

Illustrations

1. The velocity of a body of mass 10 g is $2\times10^4\ \text{ms}^{-1}$. The de Broglie wavelength associated with it will be

(A) 3.3 × 10^{-33} m   (B) 3.3 × 10^{-34} m   (C) 3.3 × 10^{-35} m   (D) 3.3 × 10^{-36} m

Ans (D)

$$\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{10\times10^{-3}\times2\times10^4} = 3.3\times10^{-36}\ \text{m.}$$

2. If particles are moving with same velocity, then maximum de-Broglie wavelength is for

(A) proton   (B) α - particle   (C) neutron   (D) β - particles

Ans (D)

$\lambda = \frac{h}{mv}$ or $\lambda \propto \frac{1}{m}$ for a given value of v.

Among the given particles, mass of a β particle is least.

Since m for β particles is least, $\lambda_{\text{de Broglie}}$ for β-particle is maximum.

3. The energy that should be supplied to an electron to reduce its de Broglie wavelength from 10^{-10} m to 0.5×10^{-10} m will be

(A) four times the initial energy (B) equal to the initial energy

(C) twice the initial energy (D) thrice the initial energy

Ans (D)

$$\lambda = \frac{h}{\sqrt{2mE_k}} \text{ or } \lambda \propto \frac{1}{\sqrt{E_k}} \text{ or } E_k \propto \frac{1}{\lambda^2}$$

$$\therefore \frac{E_2}{E_1} = \left(\frac{\lambda_1}{\lambda_2}\right)^2 = \left(\frac{10^{-10}}{0.5\times10^{-10}}\right)^2 = 4$$

or $E_2 = 4E_1$

$\therefore$ Energy to be supplied = $4E_1 - E_1 = 3E_1$

4. The de Broglie wavelength of a neutron when its kinetic energy E_k is λ. Its wavelength when its kinetic energy is 4 E_k is

(A) 4λ (B) 2λ (C) $\frac{\lambda}{2}$ (D) $\frac{\lambda}{4}$

Ans (C)

Kinetic energy, $K = \frac{1}{2} mv^2$ or $mv = \sqrt{2mK}$

$\therefore$ de Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mK}}$;

$$\therefore \lambda \propto \frac{1}{\sqrt{K}} \quad \therefore \frac{\lambda'}{\lambda} = \sqrt{\frac{K}{4K}} = \frac{1}{2} \text{ or } \lambda' = \frac{\lambda}{2}$$

5. The wavelength corresponding to a beam of electrons whose kinetic energy is 100 eV is
($h = 6.6 \times 10^{-34}$ J s; 1 eV = 1.6×10^{-19} J ; $m_e = 9.1 \times 10^{-31}$ kg)

(A) 1.2 Å (B) 2.4 Å (C) 3.6 Å (D) 4.8 Å

Ans (A)

We know that kinetic energy,

$$E_k = \frac{p^2}{2m}; \therefore p = \sqrt{2mE_k}$$

de Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE_k}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times100\times1.6\times10^{-19}}}$$

i.e., $\lambda = 1.22 \times 10^{-10}$ m = 1.2 Å.

6. The de Broglie wavelength of a neutron at 927 °C is λ. Its wavelength at 27 °C is

(A) $\frac{\lambda}{2}$ (B) $\frac{\lambda}{4}$ (C) 4λ (D) 2λ

Ans (D)

We Know that, $\lambda = \frac{h}{\sqrt{3mkT}}$;

$$\text{so } \lambda \propto \frac{1}{\sqrt{T}} \quad \therefore \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{927+273}{27+273}} = 2 \text{ or } \lambda_2 = 2\lambda_1 .$$

7. The magnitude of the de-Broglie wavelength of electron (e), proton (p), neutron (n) and α-particle (α) all having the same energy of 1 MeV, in the ascending order is

(A) $\lambda_e, \lambda_p, \lambda_n, \lambda\alpha$ (B) $\lambda_e, \lambda_n, \lambda_p, \lambda\alpha$ (C) $\lambda\alpha, \lambda_n, \lambda_p, \lambda_e$ (D) $\lambda_p, \lambda_e, \lambda\alpha, \lambda_n$

Ans (C)

$$\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$$

Since $m_\alpha > m_p > m_e,\ \lambda_\alpha < \lambda_p < \lambda_e$

8. A proton and an α-particle are accelerated through the same potential difference. The ratio of their de Broglie wavelengths will be

(A) 1 : 1 (B) 1 : 2 (C) 2 : 1 (D) $2\sqrt{2}:1$

Ans (D)

$qV = \frac{1}{2}mv^2$ or $mv = \sqrt{2qVm}$

So $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2qVm}}$

i.e. $\lambda \propto \frac{1}{\sqrt{qm}}$

so $\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{q_\alpha m_\alpha}{q_p m_p}} = \sqrt{2\times 4} = 2\sqrt{2}$

9. The potential difference through which an electron should be accelerated, so that its de-Broglie wavelength is 0.05 nm is

(A) 6022 V (B) 602.2 V (C) 60.22 V (D) 6.022 V

Ans (B)

$$\lambda = \frac{h}{\sqrt{2meV}} \approx \frac{1.23}{\sqrt{V}}\text{nm}$$

$$V = \frac{1.23\times 1.23\times (10^{-9})^2}{(0.05)^2 \times (10^{-9})^2} \approx \frac{1.5}{25\times 10^{-4}} \approx 600\ \text{V}$$

10. A particle of mass M at rest decays into two particles of masses m_1 and m_2, having non-zero velocities. The ratio of the de Broglie wavelengths of the particle $\frac{\lambda_1}{\lambda_2}$ is

(A) $\frac{m_1}{m_2}$ (B) $\frac{m_2}{m_1}$ (C) 1 (D) $\sqrt{m_2/m_1}$

Ans (C)

Using law of conservation of momentum we have, $0 = m_1v_1 + m_2v_2$

$\therefore |m_1v_1| = |m_1v_2|$ $\therefore \frac{\lambda_1}{\lambda_2} = \frac{\left(\frac{h}{m_1v_1}\right)}{\left(\frac{h}{m_2v_2}\right)} = 1$

11. A hydrogen atom is in an excited state. Its total energy is –3.4 eV

(A) The kinetic energy of the electron in the atom is 3.4 eV

(B) de Broglie wavelength associated with the electron in the atom is 6.63 Å

(C) Angular momentum of the electron about the nucleus is $\frac{7h}{22}$.

(D) (A), (B) and (C)

Ans (D)

$K_2 = -(-E) = 3.4\text{eV}$

Quick calculation

$$\lambda_{electron} = \frac{h}{\sqrt{2meV}} \approx \frac{12.2}{\sqrt{V}}$$

$$\lambda_{electron} = \frac{12.2}{\sqrt{3.4}}\ \text{Å} \approx 6\ \text{Å}$$

$$n^2 = \frac{-13.6 \text{ eV}}{-3.4 \text{ eV}} = 4 \Rightarrow n = 2$$

$$\lambda_2 = \frac{h}{\sqrt{2mK_2}} = \frac{6.625\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times3.4\times1.6\times10^{-19}}}$$

$$= \frac{6.625\times10^{-8}}{3\times8\sqrt{17}} \approx \frac{6.625\times10^{-8}}{3\times32} = \frac{6.625\times10^{-8}}{96} \approx 6.63 \text{ Å}$$

$$L_2 = \frac{nh}{2\pi} = \frac{2h}{2\pi} = \frac{7h}{22}$$

12. If the uncertainty in the position of an electron is 10^{-10} m, then the uncertainty in its momentum (in kg ms^{-1}) measurement will be nearly

(A) 6.6×10^{-26} (B) 10^{-24} (C) 3.3×10^{-24} (D) 6.6×10^{-24}

Ans (B)

By uncertainty principle,

$$\Delta x \cdot \Delta p \approx \frac{h}{2\pi}$$

$$(10^{-10})\Delta p \approx \frac{6.6\times10^{-34}}{6.28} \qquad \Delta p \approx \frac{10^{-34}}{10^{-10}} = 10^{-24} \text{ kg ms}^{-1}$$

13. Consider the following statements

(i) A mechanical wave can travel in vacuum.

(ii) electromagnetic wave can travel through vacuum.

(iii) the velocity of a photon is not the same in different media

(iv) wavelength of a de Broglie wave depends upon the velocity of a moving particle

The wrong statement is

(A) (iv) (B) (iii) (C) (ii) (D) (i)

Ans (D)

For the propagation of a mechanical wave, a material medium is essential.

14. On the basis of uncertainty principle it can be shown that

(A) electrons may not exist in a nucleus

(B) electrons cannot exist in a nucleus

(C) an electron repels a proton within a nucleus

(D) the attraction between an electron and a proton is very small within a nucleus

Ans (B)

The uncertainty principle shows that if an electron is to be a constituent particle of a nucleus its energy should be of the order of 20 MeV. But in β-decay, maximum energy measured is about 1 MeV. Thus, an electron cannot exist in a nucleus.

15. Two neutral particles of mass m and 2 m have equal kinetic energies. The ratio of their de-Broglie wavelengths is

(A) indeterminate (B) 1 : 2 (C) $1 : \sqrt{2}$ (D) $\sqrt{2} : 1$

Ans (D)

$$\lambda = \frac{h}{mv}$$

Kinetic energy $K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2K}{m}}$ or $\lambda = \frac{h}{\sqrt{2mK}}$

where K is the kinetic energy. Since the kinetic energy is same for both the particles,

$$\lambda \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{\sqrt{m_2}}{\sqrt{m_1}} = \sqrt{\frac{2m}{m}} = \frac{\sqrt{2}}{1}$$

16. The de-Broglie wavelength of the electron in the ground state of a hydrogen atom is

(A) 0.53 Å (B) 1.06 Å (C) 1.67 Å (D) 3.33 Å

Ans (D)

When the electron is in the ground state of a hydrogen atom, then it is in the first orbit whose radius r = 0.53 Å. For first orbit, the circumference is equal to de-Broglie wavelength.

Therefore, $\lambda = 2\pi r = 2\times\frac{22}{7}\times 0.53\text{Å} = 3.33\text{Å}$

17. The energy E of a photon is equal to the kinetic energy of a proton. Let λ_1 be the de-Broglie wavelength of the proton and λ_2 be the wavelength of the photon. The ratio $\frac{\lambda_1}{\lambda_2}$ is proportional to

(A) E (B) $E^{\frac{1}{2}}$ (C) E^{-1} (D) E^{-2}

Ans (B)

- For a proton, $E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{m^2v^2}{m}$ or $mv = \sqrt{2mE}$

$$\lambda_1 = \frac{hc}{mv} = \frac{h}{\sqrt{2mE}}$$

- For a photon, $E = hv_2 = \frac{hc}{\lambda_2}$ or $\lambda_2 = \frac{hc}{E}$

$$\therefore \frac{\lambda_1}{\lambda_2} = \frac{\frac{h}{\sqrt{2mE}}}{hc/E} \propto \frac{E}{\sqrt{E}} = E^{\frac{1}{2}}$$

18. An electron accelerated under a potential difference V has a certain wavelength λ. The mass of a proton is about 1840 times of the mass of an electron. If the proton should have the same wavelength λ, then it should be accelerated using a potential difference of

(A) V (B) 1840 V (C) $\frac{V}{1840}$ (D) $V\sqrt{1840}$

Ans (C)

Given, $\lambda_p = \lambda_e$

or $\frac{h}{\sqrt{2m_pq_pV_p}} = \frac{h}{\sqrt{2m_eq_eV}}$ or $m_pq_pV_p = m_eq_eV$ or $V_p = \left(\frac{m_e}{m_p}\right)\left(\frac{q_e}{q_p}\right)V$

$$= \frac{1}{1840}\times 1\times V = \frac{V}{1840}V$$

Each of the following questions consists of a Statement−I and a Statement−II. Examine both of them and select one of the options using the following codes:

(A) Statement-I and Statement-II are true and Statement-II is the correct explanation of Statement-I.

(B) Statement-I and Statement-II are true but Statement-II is not the correct explanation of Statement -I.

(C) Statement-I is true, but Statement -II is false.

(D) Statement-I is false, but Statement -II is true.

19. **Statement I:** The working of an electron microscope is based on de Broglie's hypothesis.

Statement II: A beam of electrons behaves as a wave which can be converged by using electric and magnetic fields.

Ans (A)

20. **Statement I:** The de Broglie wavelength of an electron accelerated through 961 V is around 0.4 Å.

Statement II: The concept of matter waves is charge independent.

Ans (B)

$$\lambda = \frac{h}{\sqrt{2meV}} \Rightarrow \lambda_{ele} \approx \frac{12.23}{\sqrt{V}}\text{Å} \approx \frac{12.23}{\sqrt{961}} = 0.4 \text{ Å}$$

NCERT LINE BY LINE QUESTIONS

1. Work function depends on [NCERT Pg. 387]
   (1) Metal only
   (2) Nature of surface only
   (3) Both metal and nature of surface
   (4) Threshold frequency

2. Saturation photoelectric current [NCERT Pg. 391]
   (1) Increase with increase in plate potential
   (2) Increase with decrease in plate in plate potential

(3) Is independent of plate potential

(4) Increase with increase in frequency

3. Monochromatic light of frequency 6×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3}W. The number photons emitted per second by source is [NCERT Pg. 396]

(1) 5.0×10^{15} (2) 5.0×10^{16} (3) 5.0×10^{17} (4) 5.0×10^{18}

4. A particle is moving three times as fast as an electron. The ratio of de-Broglie wavelength of particle to that of electron is 1.813×10^{-4}. The particle may be [NCERT Pg. 402]

(1) Proton **(2)** Deutron (3) a-particle (4) Triton

5. An electron microscope uses electrons accelerated by a voltage of 50 kV. how does the resolving power of this electron microscope compare with that of an optical microscope which uses yellow light? [NCERT Pg. 411]

(1) 10^4 times (2) 10^5 times (3) 10^6 times (4) 10^3 times

6. A particle is dropped from a height H. The de-Broglie wavelength of the particle as a function of height is proportional to [NCERT Pg. 400]

(1) H (2) $H^{1/2}$ (3) H° (4) $H^{-1/2}$

7. A proton and an a-particle are accelerated through the same potential difference. The ratio of de-Broglie wavelength λ_p to that λ_α is [NCERT Pg. 400]

(1) $\sqrt{2}:1$ (2) 2 : 1 (3) $2\sqrt{2}:1$ (4) $1:\sqrt{2}$

8. Which of the following statements is incorrect about the photons? [NCERT Pg. 396]

(1) Momentum of photon is (2) Rest mass of photon is zero

(3) Photons exert no pressure (4) Energy of photon is frv

9. The wavelength of matter wave is independent of [NCERT Pg. 398]

(1) Mass (2) Velocity (3) Kinetic energy (4) Charge

10. Which experiment best support the theory that matter has wave nature? [NCERT Pg. 403]

(1) Photoelectric effect (2) α -scattering experiment

(3) Davisson and Germer experiement (4) Compton effect

11. Which among the following phenomenon shows particle nature of light? [NCERT Pg. 395]

(1) Photoelectric effect (2) Interference

(3) Polarization (4) Matter waves

12. Which of the following device is some times called electric eye? [NCERT-Pg399]

(1) Light emitting diode (2) Photocell

(3) Electric generator (4) Integrated chip

13. For a certain metal, incident frequency v is five times of threshold frequency v_o and maximum speed of coming out photoelectrons is 8 X 10^6 m/s. If $v = 2v_o$, the maximum speed of photoelectrons will be [NCERT Pg. 395]

(1) 4 x 10^6 m/s (2) 6 x 10^6 m/s (3) 3 x 10^6 m/s (4) 1 x 10^6 m/s

14, An electron is moving with an initial velocity $\vec{v} = v_0\hat{i}$ enters in a uniform magnetic field $\vec{B} = B_0\hat{j}$. Then its de-Broglie wavelength [NCERT Pg. 400]

(1) Increase with time (2) Decrease with time

(3) Remains constant (4) Increases and decreases periodically

15. For a wavelength of 400 nm, kinetic energy of emitted photoelectron is twice that for a wavelength of 600 nm from a given metal. The work function of metal is [NCERT Pg. 395]

(1) 1.03 eV (2) 2 11 eV (3)4.14eV (4) 2.43 eV

16. The linear momentum of a 3 MeV photon is [NCERT Pg. 398)

(1) 0.01 eV s m^{-1} (2) 0.02 eV s m^{-1}

(3) 0.03 eV s m^{-1} (4) 0.04 eV s m^{-1}

17. A particle of mass 4m at rest decays into two particles of mass m and 3m. The ratio of de-Broglie wavelength of two particles will be [NCERT Pg. 400)

(1) $\frac{1}{2}$ (2) 4 (3) 2 (4) 1

18. In a photon particle collision (such as photon electron collision). Which of the following may not be conserved? (NCERT Pg. 396]

(1) Total energy (2) Number of photons

(3) Total momentum (4) None of above

19. If the momentum of an electron is changed by P, then the de-Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be [NCERT Pg 400]

(1) 200P (2) 400P (3) $\frac{P}{200}$ (4) 100P

20. The phenomena of photoelectric effect was first explained by [NCERT Pg. 395]

(1) Albert Einstein (2) Heinrich Hertz

(3) Wilhelm Hallwachs (4) Philipp Lenard

NCERT BASED PRACTICE QUESTIONS

1. The Photoelectric current is directly proportional to

(a) Intensity of incident light (b) Frequency

(c) Both (a) and (b) (d) None of these

2. The maximum kinetic energy of the photoelectrons depends upon
(a) Intensity of Incident light (b) Frequency
(c) Both (a) and (b) (d) None of these

3. The momentum of a photon of energy I MeV in kg ms^{-1} will be
(a) 10^{-22} (b) 0.33×10^{6} (c) 5×10^{-22} (d) 7×10^{-24}

4. The emission of electrons is possible by
(a) Photoelectric effect (d) thermionic effect
(c) Both (a) & (b) (d) None of these

5. Which of the following has highest specific charge?
(a) Positron (b) Proton (c) Helium (d) None of these

6. The magnitude of saturation photoelectric current depends upon
(a) frequency (b) Intensity (c) Work function (d) Stopping potential

7. The thermions are
(a) photons (b) Positron (c) Proton (d) Electrons

8. The rest mass of photon is
(a) 1.76×10^{-35}Kg (b) Zero (c) 9×10^{-31}Kg (d) 1a.m.u

9. Energy of the photon cannot be represented by
(a) hv (b) hcλ (c) hc/ λ (d) hcυ

10. The momentum of a photon is p . the corresponding wavelength is
(a) h/p (b) hp (c) p/h (d) $h/\sqrt{p}$

11. Velocity of photon is proportional to
(a) $\frac{1}{\sqrt{\nu}}$ (b) $\sqrt{\nu}$ (c) V (d) V^2

12. Monochromatic light of frequency $6.0 \text{ X } 10^{14}$ Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. What is the energy of a photon the light beam?
(a) 398×10^{-19} J (b) 3.98×10^{-19} J (c) 3.8×10^{-19} J (d) None

13. The work function of cesium is 2.14 eV. Find the threshold frequency for cesium.
(a) 5.16×10^{14} Hz (b) 51.6×10^{14} Hz (c) 5.16×10^{10} Hz (d) None

14. What is the de Broglie wavelength associated with an electron moving with a speed of 5.4 m/s ?
(a) 0.135 mm (b) 0.135 nm (c)135 mm (d) None

15. An electron, an particle, and a proton have the same kinetic energy. Which of these particles has the shortest de Broglie wavelength?
(a) -particle (b) Both (c) proton (d) None

16. A particle is moving three times as fast as an electron. The ratio of the de Broglie wavelength of the particle to that of the electron is 1.813. Calculate the particle's mass.

(a) 1.67510^{-27} kg (b) 1.67510^{-26} kg (c) 16.7510^{-27} kg (d) None

17. What is the de Broglie wavelength associated with an electron, accelerated through a potential difference of 100 volts.

(a) 0.125nm (b) 0.123nm (c) 0.130nm (d) None

18. The work function of cesium metal is 2.14 eV. When light of frequency 6is incident on the metal surface, photo emission of electrons occurs. What is the maximum kinetic energy of the emitted electrons?

(a) 0.54×10^{-19} J (b) 54×10^{-19} J (c) 0.054 (d) 54.0×10^{-19} J

19. The photoelectric cut - off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photoelectrons emitted?

(a) 2.4×10^{-19} J (b) 14×10^{-19} J (c) 3.4×10^{-19} J (d) None

20. The energy flux of sunlight reaching the surface of the earth is 1.388 How many photons (nearly) per square meter are incident on the Earth per second? Assume that the photons in the sunlight have an average wavelength of 550nm.

(a) 4×10^{21} photons/m^2 s (b) 4×10^{22} photons/m^2 s

(c) 4×10^{23} photons/m^2 s (d) 4×10^{27} photons/m^2

21. In an experiment on photoelectric effect , the slope of the cut – off voltage versus frequency of incident light is found to be 4.12 Vs. Calculate the value of planck's constant.

(a) 65.9×10^{-34} Js (b) 6.59×10^{-34} Js (c) 6.9×10^{-34} Js (d) None

22. A 100W sodium lamp radiates energy uniformly in all directions. The lamp is located at the centre of a large sphere that absorbs all the sodium light which is incident on it. The wavelength of the sodium light is 589 nm.

What is the energy per photon associated with the sodium light?

(a) 3.38×10^{-19} J (b) 38×10^{-19} J (c) 3.38×10^{-34} J (d) None

23. The threshold frequency for a certain metal is 3.3 Hz. If light of frequency 8.2 is incident on the metal, predict the cut – off voltage for the photoelectric emission.

(a) 20 V (b) 200 V (c) 2.0 V (d) None

24. The work function for a certain metal is 4.2 eV. Will this metal give photoelectric emission for incident radiation of wavelength 330 nm?

(a) Yes (b) No (c) may or may not (d) None of these

25. Light of frequency 7.21 is incident on a metal surface. Electrons with a maximum speed of 6.0 m/s are ejected from the surface. What is the threshold frequency for photoemission of electrons?

(a) 4.73×10^{14} Hz (b) 47.3×10^{14} Hz (c) 47×10^{14} Hz (d) None

26. Light of wavelength 488 nm is produced by an argon laser which is used in the photoelectric effect. When light from this spectral line is incident on the emitter, the stopping (cut – off) potential of photoelectrons is 0.38 V. Find the work function of the material from which the emitter is made.

(a) 3.46×10^{-19} J (b) 34.6×10^{-19} J (c) 346×10^{-19} J (d) None

27. Calculate the momentum of the electrons accelerated through a potential difference of 56 V.

(a) 40×10^{-24} kg ms^{-1} (b) 4.04×10^{-24} kg ms^{-1}

(c) 4×10^{-24} kg ms^{-1} (d) None

28 What is the momentum of an electron with kinetic energy of 120 eV.

(a) 5.92×10^{-24} kg ms^{-1} (b) 59.2×10^{-24} kg ms^{-1}

(c) 5.92×10^{-28} kg ms^{-1} (d) None

29 What is the de Broglie wavelength of a bullet of mass 0.040 kg traveling at the speed of 1.0 km/sec.

(a) 17×10^{-35} m (b) 1.7×10^{-35} m (c) 19×10^{-35} m (d) None

30. The wavelength of light form the spectral emission line of sodium is 589 nm, Find the kinetic energy.

(a) 4.34 eV (b) 43.4 eV (c) 434 eV (d) None

31. An electron of wavelength of 1.00 nm. Find the moment of electron.

(a) 6.63 kg m/s (b) .663 kg m/s (c) 66 kg m/s (d) None

32. For what kinetic energy of a neutron will the associated de Broglie wavelength be1.40

(a) 4.174×10^{-21}eV (b) 4.174×10^{-2}eV

(c) 4.174×10^{-34}eV (d) None

33. What is the de Broglie wavelength of a nitrogen molecule in air at 300 K ? Assume that the molecule is moving with the root – mean – square speed of molecules at this temperature. (Atomic mass of nitrogen = 14.0076u)

(a) 28 nm (b) 0.28 nm (c) 0.028 nm (d) None

34 α,β and gamma rays carry some momentum, which has the longest wavelength

(a) α rays (b) β rays

(c) gamma rays (d) all have same wavelength

35 If electron, proton and helium have same momentum, then de – Broglie's wavelength decrease in order

(a) $\lambda_e > \lambda_p > \lambda_{He}$ (b) $\lambda_{He} > \lambda_p > \lambda_e$

(c) $\lambda_{He} > \lambda_e > \lambda_p$ (d) $\lambda_e = \lambda_p = \lambda_{He}$

36 Stopping potential required to reduce photoelectric current to zero

(a) Is directly proportional to the wavelength of incident radiation

(b) Is directly proportional to the frequency of the incident radiation

(c) Increases uniformly with wavelength of the incident radiation

(d) Decreases uniformly with the frequency of the incident radiation

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Wave nature, Wavefront, Reflection and Refraction

1. Wave front is the locus of all points, where the particles of the medium vibrate with the same

(1) phase (2) amplitude (3) frequency (4) period

2. Light waves travel in vacuum along the y-axis. Which of the following may represent the wave-front?

(1) x = constant (2) y = constant (3) z = constant (4) x + y + z = constant

3. Find the minimum thickness of a film which will strongly reflect the light of wavelength 598 nm. The refractive index of the material of the film is 1.25.

(1) 118 nm (2) 120 nm (3) 218 m (4) 225 mm

4. Spherical wave fronts, emanating from a point source, strike a plane reflecting surface. What will happen to these wave fronts, immediately after reflection?

(1) They will remain spherical with the same curvature, both in magnitude and sign.

(2) They will become plane wave fronts.

(3) They will remain spherical, with the same curvature, but sign of curvature reversed.

(4) They will remain spherical, but with different curvature, both in magnitude and sign.

5. Huygens concept of wavelets is useful in

(1) explaining polarisation (2) determining focal length of the lenses

(3) determining chromatic aberration (4) geometrical reconstruction of a wave front

6. According to Huygen's construction, tangential envelope which touches all the secondary spheres is the position of

(1) original wave front (2) secondary wave front

(3) geometrical wave front (4) extended wave front

7. Huygens concept of secondary wave

(1) allows us to find the focal length of a thick lens

(2) is a geometrical method to find a wave front

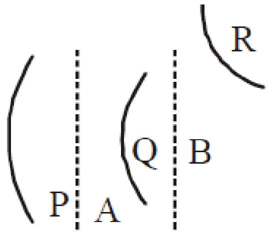
(3) is used to determine the velocity of light

(4) is used to explain polarisation

8. The wave fronts of a light wave travelling in vacuum are given by x + y + z = c. The angle made by the direction of propagation of light with the X-axis is

(1) 0º (2) 45º (3) 90º (4) $\cos^{-1}(1/\sqrt{3})$

9. Figure shows wave front P passing through two systems A and B and emerging as Q and then as R. The system A and B could, respectively, be



(1) a prism and a convergent lens (2) a convergent lens and a prism
(3) a divergent lens and a prism (4) a convergent lens and a divergent lens

Topic 2: Interference of Light, Coherent and Incoherent Sources

10. The max. Intensity produced by two coherent sources of intensity I_1 *and* I_2 will be

(1) $I_1 + I_2$ (2) $I_1^2 + I_2^2$
(3) $I_1 + I_2 + 2\sqrt{I_1 I_2}$ (4) zero

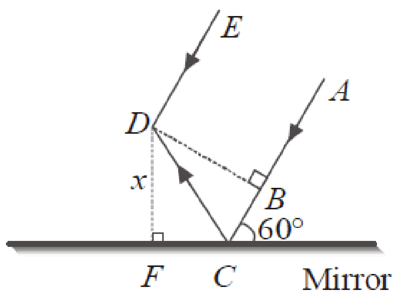
11. Two sources of light are said to be coherent, when they give light waves of same

(1) amplitude and phase (2) wavelength and constant phase difference
(3) intensity and wavelength (4) phase and speed

12. To demonstrate the phenomenon of interference, we require two sources which emit radiation of

(1) nearly the same frequency
(2) the same frequency
(3) different wavelengths
(4) the same frequency and having a definite phase relationship

13. For the two parallel rays *AB* and *DE* shown here, *BD* is the wave front. For what value of wavelength of rays destructive interference takes place between ray *DE* and reflected ray *CD*?



(1) $\sqrt{3}x$ (2) $\sqrt{2}x$ (3) x (4) $2x$

14. The ratio of intensities of two waves is 9 : 1. They are producing interference. The ratio of maximum and minimum intensities will be

(1) 10 : 8 (2) 9 : 1 (3) 4 : 1 (4) 2 : 1

15. Interference was observed in interference chamber where air was present, now the chamber is evacuated, and if the same light is used, a careful observer will see

(1) No interference (2) interference with brighter bands
(3) Interference with dark bands (4) interference fringe with larger width

16. White light falls normally on a film of soapy water whose thickness is 5×10^{-5} cm and refractive index is 1.40. The wavelengths in the visible region that are reflected the most strongly are:

(1) 5000 Å and 4000 Å (2) 5400 Å and 4000 Å
(3) 6000 Å and 5000 Å (4) 4500 Å only

17. Ratio of intensities of two waves are given by 4:1. Then the ratio of the amplitudes of the two waves is

(1) 2 : 1 (2) 1 : 2 (3) 4 : 1 (4) 1 : 4

18. Which one of the following statements is correct?
(1) Monochromatic light is never coherent.
(2) Monochromatic light is always coherent.
(3) Two independent monochromatic sources are coherent.
(4) Coherent light is always monochromatic.

19. The interfering fringes formed by a thin oil film on water are seen in yellow light of sodium lamp. We find the fringes
(1) Coloured (2) black and white (3) yellow and black (4) coloured without yellow

20. Two coherent monochromatic light beams of intensities I *and* $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are
(1) $5I$ *and* I (2) $5I$ *and* $3I$ (3) $9I$ *and* I (4) $9I$ *and* $3I$

21. The path difference between two interfering waves at a point on screen is 171.5 times the wavelength. If the path difference is 0.01029 cm. Find the wavelength
(1) $6000\times10^{-10}cm$ (2) 6000 Å (3) $6000\times10^{-8}mm$ (4) None of these

22. When a thin transparent plate of thickness t and refractive index μ is placed in the path of one of the two interfering waves of light, then the path difference changes by
(1) $(\mu+1)t$ (2) $(\mu-1)t$ (3) $\frac{(\mu+1)}{t}$ (4) $\frac{(\mu-1)}{t}$

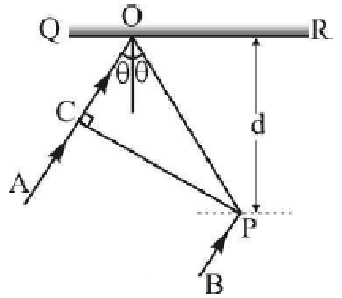
23. For observing interference in thin films with a light of wave length λ the thickness of the film:
(1) may be of any magnitude (2) should be much smaller than λ
(3) should be of the order of λ (4) should be a few thousand times of λ

24. In which of the following is the interference due to the division of wave front?
(1) Young's double slit experiment (2) Fresnel's biprism experiment
(3) Lloyd's mirror experiment (4) Demonstration colours of thin film

25. Light from two coherent sources of the same amplitude A and wavelength λ illuminates the screen. The intensity of the central maximum is I_0. If the sources were incoherent, the intensity at the same point will be
(1) $4I_0$ (2) $2I_0$ (3) I_0 (4) $I_0/2$

26. A point p is situated 90.50 and 90.58 cm away from two coherent sources. The nature of illumination of the point 'p' if the wavelength of light is 4000 Å, is
(1) bright (2) dark
(3) neither bright nor dark (4) none of these

27. In the adjacent diagram, CP represents a wave front and AO & BP, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and reflected ray OP



(1) $\cos\theta=3\lambda/2d$ (2) $\cos\theta=\lambda/4d$
(3) $\sec\theta-\cos\theta=\lambda/d$ (4) $\sec\theta-\cos\theta=4\lambda/d$

28. Sodium light ($\lambda = 6\times10^{-7} m$) is used to produce interference pattern. The observed fringe width is 0.12 mm. The angle between two interfering wave trains, is

(1) $1\times10^{-3}\ rad$ (2) $1\times10^{-2}\ rad$ (3) $5\times10^{-3}\ rad$ (4) $5\times10^{-2}\ rad$

29. Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\frac{\pi}{2}$ at point A and π at point B. Then the difference between the resulting intensities at A and B is

(1) $2I$ (2) $4I$ (3) $5I$ (4) $7I$

Topic 3: Young's Double Slit Experiment

30. Which of the following is not essential for two sources of light in Young's double slit experiment to produce a sustained interference?

(1) Equal wavelength (2) Equal intensity
(3) Constant phase relationship (4) Equal frequency

31. The fringe width in a Young's double slit experiment can be increased if we decrease

(1) width of slits (2) separation of slits
(3) wavelength of light used (4) distance between slits and screen

32. Instead of using two slits, if we use two separate identical sodium lamps in Young's experiment, which of the following will occur?

(1) General illumination (2) Widely separate interference
(3) Very bright maxima (4) Very dark minima

33. The maximum intensity of fringes in Young's experiment is *I*. If one of the slit is closed, then the intensity at that place becomes I_0. Which of the following relation is true ?

(1) $I = I_0$ (2) $I = 2I_0$
(3) $I = 4I_0$ (4) there is no relation between I and I_0

34. When we close one slit in the Young's double slit experiment, then

(1) the bandwidth is increased (2) the bandwidth is decreased
(3) the bandwidth remains unchanged (4) the diffraction pattern is observed

35. S is the size of the slit, d is the separation between the slits and D is the distance where Young's double slit interference pattern is being observed. If l be the wavelength of light, then for sharp fringes, the essential condition is:

(1) $\frac{S}{D} < \frac{\lambda}{d}$ (2) $\frac{D}{S} < \frac{\lambda}{d}$ (3) $S\lambda < dD$ (4) $SD > \lambda d$

36. In a YDSE bi-chromatic light of wavelengths 400 nm and 560 nm are used. The distance between the slits is 0.1 mm and the distance between the plane of the slits and the screen is 1m. The minimum distance between two successive regions of complete darkness is

(1) 4 mm (2) 5.6 mm (3) 14 mm (4) 28 mm

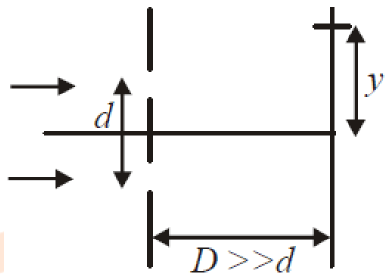
37. In a Young's double slit experiment, the separation of the two slits is doubled. To keep the same spacing of fringes, the distance D of the screen from the slits should be made

(1) $\frac{D}{2}$ (2) $\frac{D}{\sqrt{2}}$ (3) $2D$ (4) $4D$

38. In YDSE, how many maxima's can be obtained on a screen including central maxima in both sides of the central fringe if $\lambda = 3000\ \overset{0}{A}, d = 5000\ \overset{0}{A}$

(1) 2 (2) 5 (3) 3 (4) 1

39. Consider the YDSE arrangement shown in figure. If $d = 10\lambda$ then position of 8^{th} maxima is



(1) $y = \frac{D}{10}$ (2) $y = \frac{D}{3}$ (3) $y = \frac{4}{5}D$ (4) $y = \frac{4D}{3}$

40. In a Young's double-slit experiment the fringe width is 0.2 mm. If the wavelength of light used is increased by 10% and the separation between the slits is also increased by 10%, the fringe width will be

(1) 0.20 mm (2) 0.401 mm (3) 0.242 mm (4) 0.165 mm

41. In Young's double slit expt. the distance between two sources is 0.1 mm. The distance of the screen from the source is 20 cm. Wavelength of light used is 5460 Å. The angular position of the first dark fringe is

(1) 0.08° (2) 0.16° (3) 0.20° (4) 0.32°

42. In Young's double slit experiment, λ = 500nm, d = 1mm, D = 1m. Minimum distance from the central maximum for which intensity is half of the maximum intensity is

(1) $2.5\times10^{-4}m$ (2) $1.25\times10^{-4}m$ (3) $0.625\times10^{-4}m$ (4) $0.3125\times10^{-4}m$

43. If the intensities of the two interfering beams in Young's double-slit experiment are I1 and I2, then the contrast between the maximum and minimum intensities is good when

(1) $|I_1 \text{ and } I_2|$ is large (2) $|I_1 \text{ and } I_2|$ is small

(3) either I_1 or I_2 is zero (4) $I_1 = I_2$

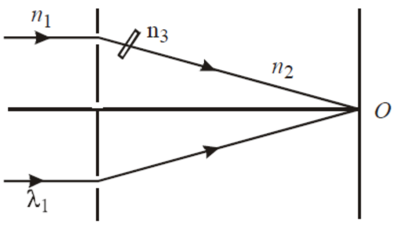
44. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is

(1) circle (2) hyperbola (3) parabola (4) straight line

45. In Young's experiment, two coherent sources are placed 0.90 mm apart and fringe are observed one metre away. If it produces second dark fringe at a distance of 1 mm from central fringe, the wavelength of monochromatic light used would be

(1) $60\times10^{-4}cm$ (2) $10\times10^{-4}cm$ (3) $10\times10^{-5}cm$ (4) $6\times10^{-5}cm$

46. In the figure shown in a *YDSE*, a parallel beam of light is incident on the slits from a medium of refractive index n_1. The wavelength of light in this medium is λ_1. A transparent slab of thickness t and refractive index is put in front of one slit. The medium between the screen and the plane of the slits is n_2. The phase difference between the light waves reaching point *O* (symmetrical, relative to the slit) is



(1) $\frac{2\pi}{n_1\lambda_1}(n_3-n_2)t$ (2) $\frac{2\pi}{\lambda_1}(n_3-n_2)t$ (3) $\frac{2\pi n_1}{n_2\lambda_1}\left(\frac{n_3}{n_2}-1\right)t$ (4) $\frac{2\pi n_1}{\lambda_1}(n_3-n_2)t$

47. Distance between screen and source is decreased by 25%. Then the percentage change in fringe width is
(1) 20% (2) 31% (3) 75% (4) 25%

48. In Young¢s double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is (separation between slits is d)
(1) $\sin^{-1}(\lambda/d)$ (2) $\sin^{-1}(\lambda/2d)$ (3) $\sin^{-1}(\lambda/3d)$ (4) $\sin^{-1}(\lambda/4d)$

49. In Young's double slit experiment, the slits are 3 mm apart. The wavelength of light used is 5000 Å and the distance between the slits and the screen is 90 cm. The fringe width in mm is
(1) 1.5 (2) 0.015 (3) 2.0 (4) 0.15

50. In Young's experiment intensity at a point on the screen is 75% of the maximum value. Minimum phase difference between the waves arriving at this point from the two slits will be
(1) 30° (2) 45° (3) 60° (4) 135°

Topic 4: Diffraction and Polarization of Light

51. If the width of the slit in single slit diffraction experiment is doubled, then the central maximum of diffraction pattern becomes
(1) broader and brighter (2) sharper and brighter
(3) sharper and fainter (4) broader and fainter.

52. When monochromatic light is replaced by white light in Fresnel's biprism arrangement, the central fringe is
(1) coloured (2) white (3) dark (4) None of these

53. The first diffraction minima due to a single slit diffraction at $\theta = 30^0$ for a light of wavelength 5000Å. The width of the slit is
(1) $5\times10^{-5}cm$ (2) $10\times10^{-5}cm$ (3) $2.5\times10^{-5}cm$ (4) $1.25\times10^{5}cm$

54. A beam of light is incident on a glass slab $(\mu = 1.54)$ in a direction as shown in the figure. The reflected light is analysed by a polaroid prism. On rotating the polaroid, (tan 57° = 1.54)
(1) the intensity remains unchanged
(2) the intensity is reduced to zero and remains at zero
(3) the intensity gradually reduces to zero and then again increase
(4) the intensity increases continuously

55. Unpolarised light of intensity 32 W m–2 passes through three polarizers such that the transmission axis of the last polarizer is crossed with that of the first. The intensity of final emerging light is 3 W m–2. The intensity of light transmitted by first polarizer will be
(1) $32Wm^{-2}$ (2) $16Wm^{-2}$ (3) $8Wm^{-2}$ (4) $4Wm^{-2}$

56. Optically active substances are those substances which
(1) produces polarised light
(2) produces double refraction
(3) rotate the plane of polarisation of polarised light
(4) converts a plane polarised light into circularly polarised light.

57. When an unpolarised light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is
(1) $\frac{1}{4}I_0$ (2) $\frac{1}{2}I_0$ (3) I_0 (4) $Zero$

58. A beam of light of $\lambda = 600nm$ from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between first dark fringe on either side of the central bright fringe is:
(1) 1.2 cm (2) 1.2 mm (3) 2.4 cm (4) 2.4 mm

59. Abeam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A. The intensity of the emergent light is

(1) I_0 (2) $I_0/2$ (3) $I_0/4$ (4) $I_0/8$

60. Unpolarised light is incident on a dielectric of refractive index $\sqrt{3}$. What is the angle of incidence if the reflected beam is completely polarised?

(1) 30° (2) 45° (3) 60° (4) 75°

61. A parallel beam of light of wavelength λ is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of the incident beam. At the second minimum of the diffraction pattern, the phase difference between the rays coming from the two edges of slit is

(1) $\lambda\pi$ (2) 2π (3) 3π (4) 4π

62. A single slit Fraunhofer diffraction pattern is formed with white light. For what wavelength of light the third secondary maximum in the diffraction pattern coincides with the second secondary maximum in the pattern for red light of wavelength 6500 Å?

(1) 4400 Å (2) 4100 Å (3) 4642.8 Å (4) 9100 Å

63. Two polaroid's are placed in the path of unpolarised beam of intensity I_0 such that no light is emitted from the second polaroid. If a third polaroid whose polarization axis makes an angle θ with the polarization axis of first polaroid, is placed between these polaroid's then the intensity of light emerging from the last polaroid will be

(1) $\left(\frac{I_0}{8}\right)\sin^2 2\theta$ (2) $\left(\frac{I_0}{4}\right)\sin^2 2\theta$ (3) $\left(\frac{I_0}{2}\right)\cos^4 \theta$ (4) $I_0 \cos^4 \theta$

64. The Fraunhofer 'diffraction' pattern of a single slit is formed in the focal plane of a lens of focal length 1 m. The width of slit is 0.3 mm. If third minimum is formed at a distance of 5 mm from central maximum, then wavelength of light will be

(1) 5000 Å (2) 2500 Å (3) 7500 Å (4) 8500 Å

65. Unpolarised light is incident on a plane sheet on water surface. The angle of incidence for which the reflected and refracted rays are perpendicular to each other is $\left(\mu \text{ of water} = \frac{4}{3}\right)$

(1) $\sin^{-1}\left(\frac{4}{3}\right)$ (2) $\tan^{-1}\left(\frac{3}{4}\right)$ (3) $\tan^{-1}\left(\frac{4}{3}\right)$ (4) $\sin^{-1}\left(\frac{1}{3}\right)$

NEET PREVIOUS YEARS QUESTIONS

1. Unpolarised light is incident from air on a plane surface of a material of refractive index 'm'. At a particular angle of incidence 'i', it is found that the reflected and refracted rays are perpendicular to each other. Which of the following options is correct for this situation? **[2018]**

(1) Reflected light is polarised with its electric vector parallel to the plane of incidence

(2) Reflected light is polarised with its electric vector perpendicular to the plane of incidence

(3) $i = \tan^{-1}\left(\frac{1}{\mu}\right)$ (4) $i = \sin^{-1}\left(\frac{1}{\mu}\right)$

2. In Young's double slit experiment the separation d between the slits is 2 mm, the wavelength λ of the light used is 5896 Å and distance D between the screen and slits is100 cm. It is found that the angular width of the fringes is 0.20°. To increase the fringe angular width to 0.21° (with same λ and D) the separation between the slits needs to be changed to **[2018]**

(1) 1.8 mm (2) 1.9 mm (3) 1.7 mm (4) 2.1 mm

3. The ratio of resolving powers of an optical microscope for two wavelengths $\lambda_1 = 4000 A^0$ and $\lambda_1 = 6000 A^0$ is **[2017]**

(1) 9 : 4 (2) 3 : 2 (3) 16 : 81 (4) 8 : 27

4. Two Polaroids P1 and P2 are placed with their axis perpendicular to each other. Unpolarised light I0 is incident on P1. A third polaroid P3 is kept in between P1 and P2 such that its axis makes an angle 45° with that of P1 . The intensity of transmitted light through P2 is **[2017]**

(1) $\frac{I_0}{4}$ (2) $\frac{I_0}{8}$ (3) $\frac{I_0}{16}$ (4) $\frac{I_0}{2}$

5. Young's double slit experiment is first performed in air and then in a medium other than air. It is found that 8th bright fringe in the medium lies where 5th dark fringe lies in air. The refractive index of the medium is nearly **[2017]**

(1) 1.59 (2) 1.69 (3) 1.78 (4) 1.25

6. In a diffraction pattern due to a single slit of width 'a', the first minimum is observed at an angle 30° when light of wavelength 5000 Å is incident on the slit. The fir1st secondary maximum is observed at an angle of : **[2016]**

(1) $\sin^{-1}\left(\frac{1}{4}\right)$ (2) $\sin^{-1}\left(\frac{2}{3}\right)$ (3) $\sin^{-1}\left(\frac{1}{2}\right)$ (4) $\sin^{-1}\left(\frac{3}{4}\right)$

7. The intensity at the maximum in a Young's double slit experiment is I_0. Distance between two slits is $d = 5\lambda$, where λ is the wavelength of light used in the experiment. What will be the intensity in front of one of the slits on the screen placed at a distance D = 10 d? **[2016]**

(1) I_0 (2) $\frac{I_0}{4}$ (3) $\frac{3}{4}I_0$ (4) $\frac{I_0}{2}$

8. In a double slit experiment, the two slits are 1 mm apart and the screen is placed 1 m away. A monochromatic light wavelength 500 nm is used. What will be the width of each slit for obtaining ten maxima of double slit within the central maxima of single slit pattern? **[2015]**

(1) 0.1 mm (2) 0.5 mm (3) 0.02 mm (4) 0.2 mm

9. For a parallel beam of monochromatic light of wavelength 'l', diffraction is produced by a single slit whose width 'a' is of the wavelength of the light. If 'D' is the distance of the screen from the slit, the width of the central maxima will be: **[2015]**

(1) $\frac{D\lambda}{a}$ (2) $\frac{Da}{\lambda}$ (3) $\frac{2Da}{\lambda}$ (4) $\frac{2D\lambda}{a}$

10. In the Young's double-slit experiment, the intensity of light at a point on the screen where the path difference is λ is K, (λ being the wave length of light used). The intensity at a point where the path difference is $\lambda/4$, will be: **[2014]**

(1) K (2) K/4 (3) K/2 (4) Zero

11. A beam of light of $\lambda = 600nm$ from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between first dark fringes on either side of the central bright fringe is: **[2014]**

(1) 1.2 cm (2) 1.2 mm (3) 2.4 cm (4) 2.4 mm

12. In a double slit experiment, when light of wavelength 400 nm was used, the angular width of the first minima formed on a screen placed 1m away, was found to be 0.2°. What will be the angular width of the first minima, if the entire experimental apparatus is immersed in water (μ_{water} = 4/3) **[NEET – 2019]**

(1) 0.266° (2) 0.15° (3) 0.05° (4) 0.1°

13. In a Young's double slit experiment if there is no initial phase difference between the light from the two slits, a point on the screen corresponding to the fifth minimum has path difference.

[NEET – 2019 (ODISSA)]

(1) $5\frac{\lambda}{2}$ (2) $10\frac{\lambda}{2}$ (3) $9\frac{\lambda}{2}$ (4) $11\frac{\lambda}{2}$

14. Angular width of the central maxima in the Fraunhofer diffraction for λ = 6000 Å is θ_0. When the same slit is illuminated by another monochromatic light, the angular width decreases by 30%. The wavelength of this light is, **[NEET – 2019 (ODISSA)]**

(1) 1800 Å (2) 4200 Å (3) 6000 Å (4) 420 Å

15. Two coherent sources of light interfere and produce fringe pattern on a screen. For central maximum, the phase difference between the two waves will be **[NEET – 2020 (Covid-19)]**

(1) zero (2) π (3) $3\pi/2$ (4) $\pi/2$

16. In Young's double slit experiment, if the separation between coherent sources is halved and the distance of the screen from the coherent sources is doubled, then the fringe width becomes: **[NEET – 2020]**

1) One-fourth 2) double 3) Half 4) Four times

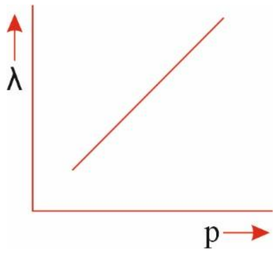
17. Assume that light of wavelength 600nm is coming from a star. The limit of resolution of telescope whose objective has a diameter of 2m is **[NEET – 2020]**

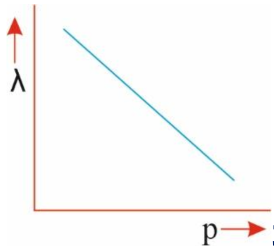
1) 6.00×10^{-7} rad 2) 3.66×10^{-7} rad 3) 1.83×10^{-7} rad 4) 7.32×10^{-7} rad

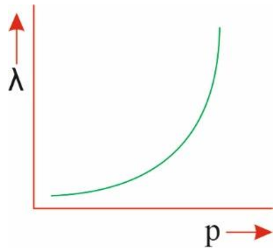
18. The Brewster's angle i_b for an interface should be: **[NEET – 2020]**

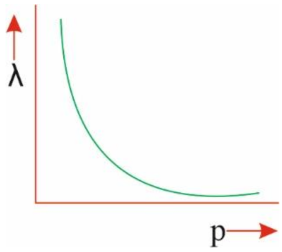
1) $i_b = 90^0$ 2) $0^0 < i_b < 30^0$ 3) $30^0 < i_b < 45^0$ 4) $45^0 < i_b < 90^0$

19. To graph which shows the variation of the de Broglie wavelength (λ) of a particle and its associated momentum (p) is **[NEET–2022]**

1) 

2) 

3) 

4) 

20. Let T_1 and T_2 be the energy of an electron in the first and second excited states of hydrogen atom, respectively. According to the Bohr's model of an atom, the ratio T_1:T_2 is **[NEET – 2022]**

1) 1 : 4 2) 4 : 1 3) 4 : 9 4) 9 : 4

21. When two monochromatic lights of frequency, n and $\frac{n}{2}$ are incident on a photoelectric metal, their stopping potential becomes $\frac{V_S}{2}$ and V_S respectively. The threshold frequency for this metal is: **[NEET – 2022]**

(1) $2n$ (2) $3n$ (3) $\frac{2}{3}n$ (4) $\frac{3}{2}n$

NCERT LINE BY LINE QUESTIONS – ANSWERS

1) c	2) c	3) a	4) a	5) b	6) d	7) c	8) c	9)d	10) c
11)a	12) b	13) a	14) c	15) a	6) a	17) d	18) b	19) a	20) a

NCERT BASED PRACTICE QUESTIONS – ANSWERS

1)a	2) b	3) c	4) c	5) a	6) b	7) d	8) b	9) c	10) a
11)b	12) b	13) a	14) b	15) a	16) a	17) b	18) a	19) a	20) a
21)b	22) a	23) c	24) b	25) a	26) a	27) b	28) a	29) b	30) a
31)a	32) b	33) c	34) d	35) d	36) b				

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	1	**2)**	2	**3)**	1	**4)**	3	**5)**	4	**6)**	2	**7)**	2	**8)**	4	**9)**	2	**10)**	3
11)	2	**12)**	4	**13)**	1	**14)**	3	**15)**	4	**16)**	1	**17)**	1	**18)**	4	**19)**	1	**20)**	3
21)	2	**22)**	2	**23)**	2	**24)**	2	**25)**	4	**26)**	1	**27)**	2	**28)**	3	**29)**	2	**30)**	2
31)	2	**32)**	1	**33)**	3	**34)**	4	**35)**	4	**36)**	4	**37)**	3	**38)**	3	**39)**	4	**40)**	1
41)	2	**42)**	2	**43)**	4	**44)**	4	**45)**	4	**46)**	4	**47)**	4	**48)**	3	**49)**	4	**50)**	3
51)	2	**52)**	2	**53)**	2	**54)**	3	**55)**	2	**56)**	3	**57)**	2	**58)**	4	**59)**	3	**60)**	3
61)	4	**62)**	3	**63)**	1	**64)**	1	**65)**	3										

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	2	**2)**	2	**3)**	2	**4)**	2	**5)**	3	**6)**	4	**7)**	4	**8)**	4	**9)**	4	**10)**	3
11)	4	**12)**	2	**13)**	3	**14)**	2	**15)**	1	**16)**	4	**17)**	2	**18)**	4	**19)**	4	**20)**	4
21)	4																		

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(1)** Wavefront is the locus of all points, where the particles of the medium vibrate with the same phase.

2. **(2)** If a plane wave of light travelling along the y-direction electric field may be along any direction in x-z plane

(i.e. y = c), hence wavefront may be represented by y = c.

3. **(1)** For strong reflection, the least optical path difference introduced by the film should by $\lambda/2$. The optical path difference between the waves reflected from the two surfaces of the film is $2\mu d$.

Thus, for strong reflection, $2\mu d = \lambda/2$.

$$d = \frac{\lambda}{4\mu} = \frac{589}{4 \times 1.25} = 118\,\text{nm}$$

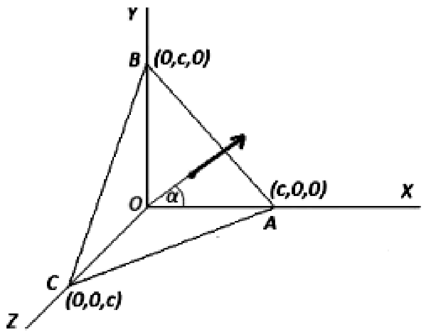
4. **(3)** They will remain spherical, with the same curvature, but sign of curvature reversed

5. **(4)** geometrical reconstruction of a wavefront

6. **(2)** secondary wavefront

7. **(2)** Huygens principle gives us a geometrical method of tracing a wavefront.

8. **(4)** The given equation of the wavefronts represent a plane that intersects each of the axes at a distance c from the origin. Let these points be named A, B and C. ABC is an equilateral triangle of side c.



The direction of propagation of light will be normal to the plane. In this case, the normal makes equal angles with each of the axes say α. Since the sum of the squares of the direction cosines equals one, here for the normal $\cos^2\alpha + \cos^2\alpha + \cos^2\alpha = 1$

$\rightarrow 3\cos^2\alpha = 1$

$\rightarrow \cos^2\alpha = 1/3$

$\rightarrow \cos\alpha = 1/\sqrt{3}$

$\rightarrow \alpha = \cos^{-1}(1/\sqrt{3})$

9. **(2)** P to Q: convergence increasing; Q to R : direction changing.

10. **(3)** As $R^2 = a^2 + b^2 + 2ab\cos\phi$

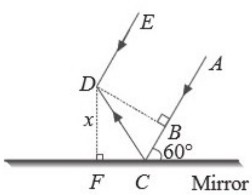
$$\therefore I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos 0^0$$

$$= I_1 + I_2 + 2\sqrt{I_1 I_2}$$

11. **(2)** For coherent sources λ is same and phase is also same or phase diff. is constant.

12. **(4)** the same frequency and having a definite phase relationship

13. **(1)** Path difference,



14. **(3)** $\frac{I_1}{I} = \frac{a_1^2}{a_2^2} = \frac{9}{1}$ or $\frac{a_1}{a_2} = \frac{3}{1}$ $\therefore \frac{I_{max}}{I_{min}} = \frac{(3+1)^2}{(3-1)^2} = \frac{16}{4} = \frac{4}{1}$

15. **(4)** As the chamber is evacuated the wavelength of the light increases slightly. Thus as the fringe width is directly proportional to wavelength the fringe width increases.

16. **(1)** For normal incidence,

$$2\mu t \cos 0^0 = (2n-1)\frac{\lambda}{2}$$

$$\text{or } \lambda = \frac{4\mu t}{(2n-1)} = \frac{4\times1.5\times5\times10^{-5}}{(2n-1)}$$

For n = 3, 4, λ = 5000 Å and 4000 Å

17. **(1)** $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{4}{1}$ $\therefore \frac{a_1}{a_2} = \frac{2}{1}$

18. **(4)** Coherent light is always monochromatic.

19. **(1)** Bright fringes are yellow and dark fringes are black.

20. **(3)** $I_{max} = I + 4I + 2\sqrt{I\times4I} = 9I$,

and $I_{min} = I + 4I - 2\sqrt{I\times4I} = I$

21. **(2)** Path difference = $171.5\lambda = \frac{343}{2}\lambda$

= odd multiple of half wavelength.

It means dark fringe is observed.

According to question, $0.01029 = \frac{343}{2}\lambda$

$$\Rightarrow \lambda = \frac{0.01029\times2}{343} = 6\times10^{-5}\text{cm} \Rightarrow \lambda = 6000\,\overset{0}{\text{A}}$$

22. **(2)** Thickness of air film = t

Optical Path = μt

Path Difference = $\mu t - t = (\mu - 1)t$

23. **(2)** should be much smaller than λ

24. **(2)** Fresnel's experiment deals with two coherent sources of equal amplitude. Lloyd's mirror experiment deals with reflection of light from a monochromatic slit source, and intends to prove wave nature of light. While in a thin film, the white light on both upper and lower surfaces split into various colors and interfere with each other. Young's Double slit experiment, deals with interference patterns caused due to division of wave fronts of two monochromatic lights

25. **(4)** For two coherent sources, $I_1 = I_2$

This is given as I_0 for maximum and zero for minimum. If there are two noncoherent sources, there will be no maximum and minimum intensities. Instead of all the intensity I_0 at maximum and zero for minimum, it will be just $I_0/2$.

26. **(1)** Bright

27. **(2)** PO = $d\sec\theta$ and CO = PO cos 2θ = $d\sec\theta\cos2\theta$

Path difference,

Δx = CO + PO = ($d\sec\theta + d\sec\theta\cos2\theta$)

Effective path difference

$$\Delta x_{eff} = d(\sec\theta + \sec\theta.\cos2\theta) + \frac{\lambda}{2}$$

For constructive interference, $\Delta x_{eff} = \lambda$

or $d(\sec\theta + \sec\theta\cos 2\theta) + \frac{\lambda}{2} = \lambda$ or $\cos\theta = \frac{\lambda}{4d}$

28. **(3)** The fringe width is given by, $\beta = \frac{\lambda D}{d}$

The angular width of fringe is given by

$$\frac{d}{D} = \frac{\lambda}{\beta} = \frac{6\times10^{-7}}{0.12\times10^{-3}} = 5\times10^{-3}\text{rad}$$

29. **(2)** $I_A = I + 4I + 2\sqrt{I+4I}\cos\pi/2 = 5I$

and $I_B = I + 4I + 2\sqrt{I\times4I}\cos\pi = I$

So, $I_A - I_B = 5I - I = 4I$

30. **(2)** Wavelength/frequency must be same and phase difference must be constant for producing sustained interference.

31. **(2)** $\beta = \frac{\lambda D}{d}$

$\therefore \beta$ increases on decreasing d, separation of slits.

32. **(1)** There will be general illumination as super imposing waves do not have constant phase difference.

33. **(3)** If a is the amplitude of wave, then

34. **(4)** Young's double slit experiment no longer remains it becomes fraunhoffer's Diffraction from single slit.

35. **(4)** $SD > \lambda d$

36. **(4)** For dark fringes of both waves at same place

or $(n+1)\times400 = n\times560$

or $n = 2.5$, and $n + 1 = 3.5$

There integer value is 5 and 7.

The distance between two regions of complete dark,

$$\Delta x = 7\frac{D\lambda}{d} = \frac{7\times1\times400\times10^{-9}}{0.1\times10^{-3}} = 28\,\text{mm}$$

37. **(3)** $\beta = \beta^{|}$ or $\frac{D\lambda}{d} = \frac{D^{|}\lambda}{(2d)}$ $\therefore D^{|} = 2D$

38. **(3)** $\Delta x_{max} = d = 5000\overset{0}{A}$. Given $\lambda = 5000\overset{0}{A}$.

As $\lambda < d < 2\lambda$, $\therefore n = 3$

39. **(4)** For maxima $d\sin\theta = n\lambda$

$$\sin\theta = \frac{n\lambda}{d} = \frac{8\lambda}{10\lambda} \Rightarrow \sin\theta = \frac{4}{5} \Rightarrow \tan\theta = \frac{4}{3}$$

Also $\tan\theta = \frac{y}{D}$ $\quad\therefore y = \frac{4D}{3}$

40. **(1)** $\beta = \frac{D\lambda}{d}$ and $\beta^{|} = \frac{D\times1.1\lambda}{1.1d} = \frac{D\lambda}{d} = \beta = 0.2\,\text{mm}$

41. **(2)** The position of nth dark fringe. So position of first dark fringe in $x_1 = \lambda D/2d$

$d = 20$ cm, $D = 0.1$mm, $\lambda = 5460$ Å, $x_1 = 0.16°$

42. **(2)** Let x be the minimum distance and I_0 be the intensity of central maximum then,

$$\frac{I_0}{2} = I_0\cos^2\left(\frac{\pi x}{\beta}\right)$$

$$\frac{\pi x}{\beta}=\frac{\pi}{4}\rightarrow x=\frac{\lambda D}{4d}=\frac{5\times10^{-7}\times1}{4\times10^{-3}}=1.25\times10^{-4}\,m$$

43. **(4)** Order of the fringe can be counted on either side of the central maximum. For example, no. 3 is first order bright fringe.

44. (4) Young's double slit experiment proved beyond a shadow of a doubt that light is a wave. The superposition of light from two slits produces an interference pattern.

45. (4) The shape of interference fringes formed on a screen in case of a monochromatic source is a straight line. Remember for double hole experiment a hyperbola is generated.

46. **(4)** Optical path difference

$$\Delta x=(\mu_1-\mu_2)t$$

47. **(4)** $x \propto D$

$\therefore$ If d becomes thrice, then X becomes $\frac{1}{3}$ times.

48. **(3)**

49. **(4)** $\beta=\frac{\lambda D}{d}=\frac{5000\times10^{-10}\times0.9}{3\times10^{-3}}m=1.5\times10^{-4}m=0.15\,mm$

50. **(3)** $\frac{3}{4}I_0=I_0\cos^2\frac{\theta}{2}\Rightarrow\cos\frac{\theta}{2}=\frac{\sqrt{3}}{2}$

$\frac{\theta}{2}=30^0\Rightarrow\theta=60^0$

51. **(2)** Width of central maximum in diffraction pattern due to single slit $=\frac{2\lambda D}{d}$

where λ is the wavelength, *D* is the distance between screen and slit and *a* is the slit width.

As the slit width *a* increases, width of central maximum becomes sharper or narrower. As same energy is distributed over a smaller area. Therefore central maximum becomes brighter.

52. **(2)** At the centre, all colours meet in phase, hence central fringe is white.

53. **(2)** d sin 30° = 1 × 5 × 10^{-7}m

d = 10^{-6}m = 10^{-4}cm = 10 × 10^{-5} cm.

54. **(3)** Here Angle of incidence, i = 57

tan 57° = 1.54

u_{glass} = tan i

It means, Here Breswster's law is followed and the reflected ray is completely polarised.

Now, when reflected ray is analysed through a polaroid then intensity of light is given by malus law.

i.e. I = $I_0\cos^2\theta$, on rotating polaroid 'θ' changes.

Due to which intensity first decreases and then increases.

55. **(2)** Intensity of polarised light transmitted from 1st polariser,

$I_1 = I_0\cos^2\theta$

but $(\cos^2\theta)_{av}=\frac{1}{2}$ So, $I_1=\frac{1}{2}I_0=\frac{32}{2}=16\,Wm^{-2}$

56. **(3)** Such substances rotate the plane of polarised light.

57. **(2)** $I=I_0\cos^2\theta$

Intensity of polarized light $=\frac{I_0}{2}$

$\Rightarrow$ Intensity of untransmitted light $=I_0-\frac{I_0}{2}=\frac{I_0}{2}$

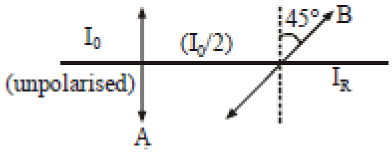
58. **(4)** Given: D = 2m; d = 1 mm = 1×10^{-3} m

$\lambda = 600$ nm $= 600 \times 10^{-6}$ m

Width of central bright fringe (= 2β)

$$= \frac{2\lambda D}{d} = \frac{2 \times 600 \times 10^{-6} \times 2}{1 \times 10^{-3}} m = 2.4\,mm$$

59. **(3)**



Relation between intensities

$$I_R = \left(\frac{I_0}{2}\right)\cos^2(45^0) = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$$

60. **(3)** $\mu = \tan i \Rightarrow i = \tan^{-1}(\mu) = \tan^{-1}(\sqrt{3}) = 60^0$

61. **(4)** Conditions for diffraction minima are

Path diff. $\Delta x = n\lambda$ and Phase diff. $\delta\phi = 2n\pi$

Path diff. $= n\lambda = 2\lambda$

Phase diff. $= 2n\pi = 4\pi \; (\because n = 2)$

62. **(3)** $x = \frac{(2n+1)\lambda D}{2a}$

For red light, $x = \frac{(4+1)D}{2a} \times 6500\,\overset{0}{A}$

For other light, $x = \frac{(6+1)D}{2a} \times \lambda\,\overset{0}{A}$

x is same for each

$\therefore 5 \times 6500 = 7 \times \lambda \Rightarrow \lambda = \frac{5}{7} \times 6500 = 4642.8\,\overset{0}{A}$

63. **(1)** $I = \left[\left(\frac{I_0}{2}\right)\cos^2\theta\right]\cos^2(90^0 - \theta)$

$$= \frac{I_0}{2}\cos^2\theta\sin^2\theta = \frac{I_0}{8}\sin^2 2\theta$$

64. **(1)** $a\sin\theta = n\lambda \Rightarrow \frac{ax}{f} = 3\lambda$

(since θ is very small so $\sin\theta \approx \tan\theta \approx \theta = x/f$)

$$\lambda = \frac{ax}{3f} = \frac{0.3 \times 10^{-3} \times 5 \times 10^{-3}}{3 \times 1}$$

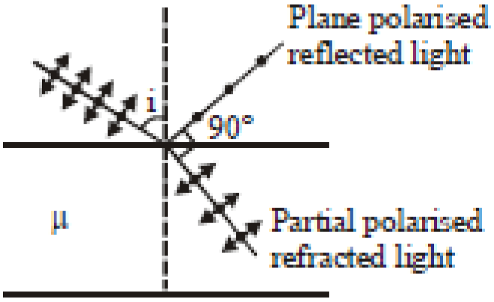
$= 5 \times 10^{-7} m = 5000\,\overset{0}{A}$

65. **(3)** Given, refractive index, $\mu = \frac{4}{3}$

According to Brewster's law when unpolarised light strikes at polarising angle i_p on an interface then reflected and refracted rays are normal to each other and is given by : $i_p = \mu \quad \therefore i_p = \tan^{-1}\left(\frac{4}{3}\right)$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(2)** When reflected light rays and refracted rays are perpendicular, reflected light is polarised with electric field vector perpendicular to the plane of incidence.



Also, $\tan i = \mu$ (i = Brewester angle)

2. **(2)** Angular width $= \frac{\lambda}{d}$

So, $0.20^0 = \frac{\lambda}{2mm} \Rightarrow \lambda = 0.20^0 \times 2$

Again, $0.21° = \frac{\lambda}{d}$

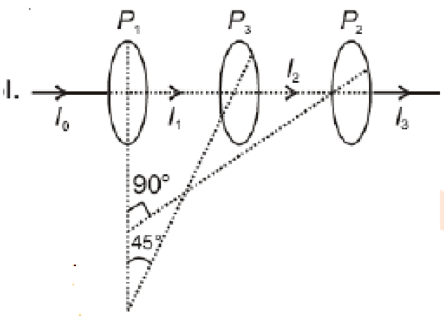
Now putting the value of λ

$d = \frac{0.20^0 \times 2mm}{0.21^0}$; $\therefore d = 1.9 nm$

3. **(2)** Resolving power of a microscope $= \frac{2\mu \sin\theta}{\lambda}$

i.e., $R \propto \frac{1}{\lambda}$ or $\frac{R_1}{R_2} = \frac{\lambda_2}{\lambda_1}$ $\therefore \frac{R_1}{R_2} = \frac{6000\,\overset{0}{A}}{4000\,\overset{0}{A}} = \frac{3}{2}$

4. **(2)** According to malus law, $I = I_0 \cos^2\theta$



$I_1 = \frac{I_0}{2}, I_2 = \frac{I_0}{2}\cos^2 45^0; = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$

$I_3 = \frac{I_0}{4}\cos^2 45^0 \Rightarrow I_3 = \frac{I_0}{8}$

5. **(3)** According to question

8th bright fringe in medium = 5th dark firing in air

$Y_{8th\,bright} = 8\frac{\lambda D}{\mu d}$

$Y_{5th\,dark} = (2\times5-1)\frac{\lambda D}{2d} = \frac{9}{2}\frac{\lambda D}{d}$

$\Rightarrow \frac{9}{2}\frac{\lambda D}{d} = 8\frac{\lambda D}{\mu d}$ or, refractive index $\mu = \frac{16}{9} = 1.78$

6. **(4)** For the first minima,

$\theta = \frac{n\lambda}{a} \Rightarrow \sin 30^0 = \frac{\lambda}{a} = \frac{1}{2}$

First secondary maxima will be at

$\sin\theta = \frac{3\lambda}{2a} = \frac{3}{2}\left(\frac{1}{2}\right) \Rightarrow \theta = \sin^{-1}\left(\frac{3}{4}\right)$

7. **(4)**

8. **(4)** Here, distance between two slits, d = 1mm = 10^{-3}m

distance of screen from slits, D = 1 m

wavelength of monochromatic light used, λ = 500nm = 500 × 10^{-9}m

width of each slit a =?

Width of central maxima in single slit pattern $= \frac{2\lambda D}{a}$

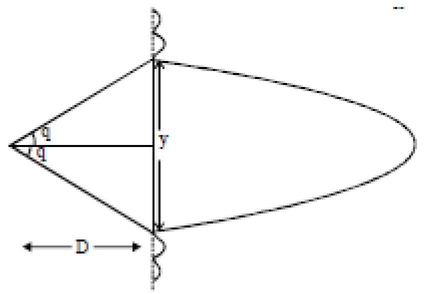
Fringe width in double slit experiment $\beta = \frac{\lambda D}{d}$

So, required condition $\frac{10\lambda D}{d} = \frac{2\lambda D}{a}$

$\Rightarrow a = \frac{d}{5D} = \frac{1}{5} \times 10^{-3} m = 0.2\,mm$

9. **(4)** Linear width of central maxima y

$= D(2q) = 2Dq = \frac{2D\lambda}{a} \quad \therefore q = \frac{\lambda}{a}$



10. **(3)** For path difference λ, phase difference $= 2\pi$ rad.

For path difference $\frac{\lambda}{4}$, phase difference $= \frac{\pi}{2}$ rad.

As K = $4I_0$ so intensity at given point where path difference is $\frac{\lambda}{4}$

$K^| = 4I_0 \cos^2\left(\frac{\pi}{4}\right)\left(\cos\frac{\pi}{4} = \cos 45^0\right) = 2I_0 = \frac{K}{2}$

11. **(4)** Given: D = 2m; d = 1 mm = 1 × 10^{-3} m

λ = 600 nm = 600 × 10^{-6} m

Width of central bright fringe (= 2β)

$= \frac{2\lambda\beta}{d} = \frac{2 \times 600 \times 10^{-6} \times 2}{1 \times 10^{-3}}$ m

= 2.4 × 10^{-3} m = 2.4 mm

12.

$\theta' = \theta/\mu$

$\therefore \quad \theta' = \frac{0.2^\circ}{4/3} = 0.15^\circ$

13. Path difference for nth minima $= (2n-1)\frac{\lambda}{2}$

For fifth minima $(n=5) = \frac{9\lambda}{2}$

14. Angular width $\propto \frac{\lambda}{d}$

$\Rightarrow \frac{\theta_0}{0.7\theta_0} = \frac{\frac{6000\overset{0}{A}}{d}}{\frac{\lambda}{d}} \Rightarrow \lambda = 4200\overset{0}{A}$

15. For central maximum, the phase difference between the two waves will be zero.

16. $\beta = \frac{\lambda D}{d}$; $\beta' = \frac{\lambda 2D}{\frac{d}{2}}$

$\beta' = 4\beta$

Fringe with becomes 4 times

17. $\Delta\theta = \frac{1.22\lambda}{d} = \frac{1.22\times 6\times 10^{-7}}{2} = 3.66\times 10^{-7}\, rad$

18. $\tan i_p = \frac{\mu_D}{\mu_R}$

$\mu_D > \mu_R \Rightarrow \frac{\mu_D}{\mu_R} > 1 \Rightarrow \tan i_P > 1 \Rightarrow i_P > 45^0$

$\therefore 45^0 < i_P < 90^0$

19. $\lambda \propto \frac{1}{p} \Rightarrow$ Rectangular hyperbola

20. $T = \frac{13.6}{n^2} \Rightarrow T \propto \frac{1}{n^2}$

$\therefore$ here $n_1 = 2, n_2 = 3$

$\frac{T_1}{T_2} = \frac{9}{4}$

21. $V_0 e = h\nu - w_0$

$\frac{v}{2} e = h\nu - \omega_0 \ldots..(1)$

$ve = \frac{h\nu}{2} - \omega_0 \ldots..(2)$

Solving above two equations and substituting $\omega_0 = h\nu_0$ we get

$\frac{3h\nu}{4} = \frac{h\nu_0}{2}$

$\nu_0 = \frac{3}{2}\nu$